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Cumulative and residual effects of compost in different crop rotations under sandy soil conditions

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Cropping sequences has been shown to increase crop yields and improve land utilization in many cases, through building up organic matter in poor soils which can be enhanced and improved crop production, as well as better quality. The objective of the current work was to determine the effect of application of organic compost at the rate of 10 m^3 fd^{-1} under dissimilar crop rotation. So, field trials were conducted in sandy soil with four field crops in two different crop rotations in 4 successive winter and summer seasons. The treatments were: no compost (as control), compost applied annually (cumulative) or two treatments applied in alternate seasons (residual). The results indicated that crop yields from the seasonal application of compost were generally significantly greater than those resulting from applications made in alternate seasons in the two rotations. Significant differences were also observed between the two alternate seasonal applications of organic compost compared with the residual effect of compost applied in the previous season. The nutrient contents of wheat were small, being below the levels normally recommended for optimum production and trace element concentrations were adequate, except for copper which was low. A similar magnitude was reported for berseem except for zinc which achieved adequacy levels under cumulative compost applications. The present data highlight the major cumulative and residual agronomic value of compost in arable crop production on reclaimed lands for different crop rotations under such impoverished soils. It could be concluded from the existing study that selecting a proper cropping sequence along with managing organic fertilizer programs can produce higher yield, maintain soil health and improve crop production without jeopardizing soil native nutrients and soil nutrients balance.
Keywords: Compost, cropping sequences, crop production, nutrients, yields.

INTRODUCTION

Soils play an important role in the production of food and feed for a growing world population. A combination of population growth, soil degradation, dietary changes, soil properties, agricultural production, and the fate of soil nutrients. Soil resources around the world vary dramatically in the availability of essential nutrients. Soil degradation has been identified on most of the world's agricultural lands in both intensive commercial and subsistence farming systems. To reverse the current trend of declining soil fertility, we need to build soil nutrient stocks through a variety of practices, including the addition of soil organic matter with and without mineral fertilizers. Among other practices, organic farming is a key practice that relies on improving both soil properties and productivity. Organic fertilizers play an important role in maintaining soil fertility to promote higher crop productivity characterized by high demand and consumer desire (Regina *et al.*, 2012). Application of organic fertilizers may improve soil physical properties through increased soil cohesion, but smallholder farmers in new reclamation lands are not practicing any application of organic fertilizers and not have a fertilizer application strategy. (Shukla *et al.*, 2003; Hati *et al.*, 2007; Zhang and Fang, 2007), demonstrated that organic fertilizers improve aggregate stability, whereas (Duiker and Lal, 1999; Barzegar *et al.*, 2002; Rachman *et al.*, 2003; Pernes-Debuyserand and Tessier, 2004; McVay *et al.*, 2006), reported that organic fertilizers decrease in the volume of micro pores while (Hati *et al.*, 2007) reported increasing macro pores], in the same context, organic fertilizers increase saturated hydraulic conductivity (Anderson *et al.*, 1990; Ndiaye *et al.*, 2007) and water infiltration rate (Ghuman and Sur, 2001; Miller *et al.*, 2002; Bhattacharyy *et al.*, 2007), moreover, improve soil water-holding capacity at both field capacity and wilting point (Sharma and Bhushan, 2001; Pernes-Debuyserand and Tessier, 2004; Zhang *et al.*, 2006;

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Rasool *et al.*, 2007; Hati *et al.*, 2007; Zhang and Fang, 2007]. Regular application of compost will increase soil organic matter and nutrient contents which is reflected in increasing benefits to soil physical properties, soil nutrients content, and crop nutrition. While fertilizer efficiency has shown that substantial yield benefits can be achieved by using applications of compost, usually in excess of those achieved by recommended rates of fertilizer (Abd El Lateef *et al.*, 2019a; Al-Suhaibani *et al.*, 2020; Selim, 2020). Compost application should be adjusted to avoid the potential negative effects on crop production to consider the changes that may occur due to an excess of nutrients which may cause luxuriant vegetative growth at the expense of economic yield. Such effects were clearly shown by specific trials in the Cairo Sludge Disposal Study (CSDS, 1999), which revealed that there are sensitive crops such as sesame and cotton under high seasonal rates of compost, other crops could also be adversely affected, such as cereals where excessive growth weakens the straw resulting in the crop lodging and difficulty in harvesting. Therefore, adjusting compost rate and seasonal applications could share in improving crop yields especially under different crop rotations. (Leinonen and Lannoitus 2000; Thorup-Kristensen *et al.*, 2003) reported that in specialized crop farms where the use of animal manure is limited, green manures provide the most effective way to improve the nitrogen supply for succeeding crops. While, (Gong *et al.*, 2009; Enke *et al.*, 2010) found that long-term addition of organic manure has the most beneficial effect on grain yield of wheat and maize. Also, (Tejada and Gonzalez, 2003) showed that compost application in 2-continuous years increased the number of grains spike^{-1}, 1000 grain weight and the number of spikes and grain wheat yield. This positive effect was mainly due to a better N supply released from the compost application. According to (Uhlen, 1991), higher residual N percentages in the soil with N added in farmyard manure may largely be due to the much lower crop utilization percentages for farmyard manure N in the first year. Also in this domain, (Abd El Lateef *et al.*, 2019b) reported that regular addition of organic waste, especially composted ones, improves soil physical properties, mainly by increasing aggregate stability and decreasing soil bulk density and indirectly contributed to soil fertility. The best agricultural performance of compost is often obtained at the highest rate and highest application frequency of application, in addition, using these strategies had additional positive effects such as the slow release of nitrogen fertilizers. Long-term application of high compost rates increases yields by up to 250%.

Another factor that keeps crops productive is crop rotation. Macholdt *et al.* (2020) considered planting sequence and nutrient management as the most important agronomic factors for maximizing the yield potential of wheat cultivation systems regarding current and future variable challenges (e.g. Climate change, sustainable crop production, food security for a growing world population, etc.), and the long-term impact of different fertilization strategies on the two main drivers of crop production, stability and soil fertility in intensive agricultural systems. It is important to assess impacts (Albers *et al.*, 2017; Knapp and van der Heijden, 2018) to help develop resilient crop production systems for the future Berti *et al.*, (2016). Crop rotation systems can be involved in maintaining nutrient status and soil properties. (Danso and Papastylianou, 1992; Khalil *et al.*, 2004; Nawar, 2004) in separate studies found that planting maize after legumes increased maize growth, yield and yield attributes. In addition, (Khalil *et al.*, 2011) reported that sunflower growth increased with crop rotation, with legume proportions increasing as the legume approached the sunflower. Sustainable crop rotation achieves crop yield advantages (Sindelar *et al.*, 2015; Schlegel *et al.*, 2017). Including perennials in crop rotation is considered an important tool for increasing soil fertility due to the positive effect of perennials on soil organic matter (SOM) (Persson *et al.*, 2008). Yield of wheat was relatively lower in double summer cropping (4-year rotation) than in single-summer cropping (3-year rotation). (Schlege *et al.*, 2019). Cultivation of legumes increases the mobility of phosphorus compounds in the soil and enriches the soil with organic matter (Tripolskaya, 2005). Lastly, alleviating soil nutrient constrains through organic fertilizer application and proper crop rotation could be suggested as an effective way of improving soil productivity and consequently contributing to keep food demands, guaranteeing food security, maintaining profitability and safeguarding zero poverty and sustainability.

Therefore, the objective of the current trials was to demonstrate the cumulative and residual effects of compost at 10 $m^3 fd^{-1}$ over a number of seasons applied in two crop rotations grown in sandy soil on crop yield, nutrient contents of the economic crop components and some soil characteristics.

MATERIALS AND METHODS

Field trials were conducted with eight field crops in two crop rotations including (four crops in each crop rotation) in four successive seasons (winter and summer seasons of winter 2017/18, summer 2018, winter 2018/19 and summer 2019) on a private farm, Tawfiq El Hakim village Nubaria Province, Behaira Governorate, Egypt, in a newly reclaimed desert land. The objectives of the current trials were to demonstrate the cumulative and residual effects of compost applied at 10 m^3 fd^{-1} over a number of seasons. The chemical composition of the compost applied to the trials is presented in Table 1 and compost treatments and the sequence of the crops grown in each crop rotation and season (Table 2). There were four treatments: no compost was applied (control), compost was applied annually (cumulative), or applied in alternate years (residual). The layout for compost treatment application is

Table 1. Analysis of Compost applied to the field trials.

Parameter		%				ppm			
PH	C/N	OM	N	P	K	Fe	Mn	Zn	Cu
7.5	14.1	13.29	1.35	0.52	2.7	161	310	61	35

Table 2. Compost treatment and the sequence crops grown in each crop rotation and season.

Treatment code	Crop rotation I	Crop rotation II	Season			
			Winter 2017/18	Summer 2018	Winter 2018/19	Summer 2019
O/O/O/O	Wheat	Barley	No compost	No compost	No compost	No compost
C/O/C/O	Forage maize	Sesame	10 m^3 fd^{-1}	No compost	10 m^3 fd^{-1}	No compost
O/C/O/C	Wheat	Berseem	No compost	10 m^3 fd^{-1}	No compost	10 m^3 fd^{-1}
C/C/C/C	Grain maize	Grain sorghum	10 m^3 fd^{-1}	10 m^3 fd^{-1}	10 m^3 fd^{-1}	10 m^3 fd^{-1}

Note: O = no compost applied; C = compost applied at 10 m^3 fd^{-1} in the allocated seasons

illustrated in Fig. 1. Two crops were grown each year and the treatments were replicated six times to provide a high degree of precision in the statistical analysis of the crop performance and plot size was 10 m × 10 m. the experimental design was Complete Randomized Block Design (CRBD). Fertilizer was applied at a uniform rate to all plots at the recommended rates for the crops, so the control represents normal farmer practice. Fertilizers were applied according to the normal recommended rates in Egypt for each crop. Nitrogen, phosphorus and potassium were applied as ammonium nitrate (33.5% N), calcium super phosphate (15.5% P_2O_5), and potassium sulphate (48% K_2O), respectively. The treatments are illustrated in Table 2, showing the sequence of compost application and crops grown in each season.

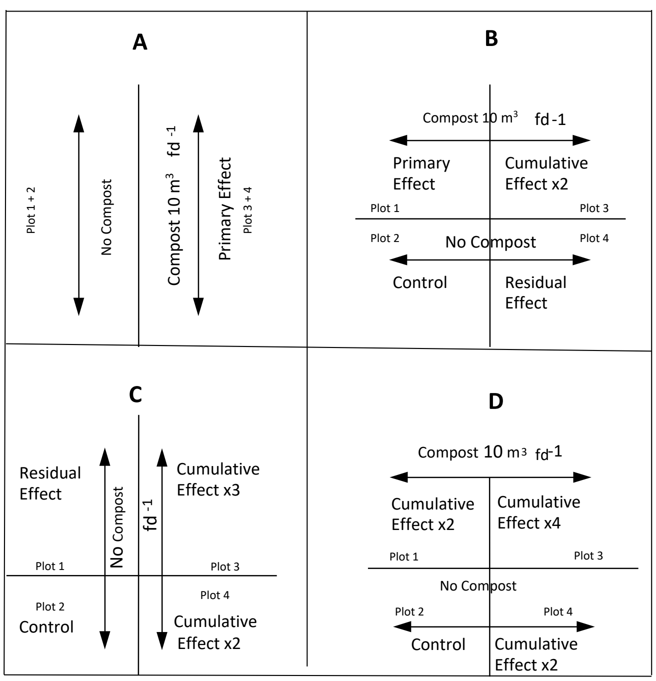

Figure 1. The layout for compost treatment application to obtain primary, residual and cumulative effects.

Note: A, B, C and D 1st, 2nd, 3rd and 4th seasons. Arrows refer to the direction of compost application each season. During the two crop sequences the crops were routinely inspected for weed control. At crop maturity, the growth characteristics and yield components were assessed according to the type of the crop. The yield and yield components measurements were determined. The conventional assessment practices were followed to provide mean individual plot yield of forage fresh and dry weights biological, straw, and grain or seed yield fd^{-1}. This research will focus only on the economic yield parameters.

Crop quality**:** Samples of grains or seeds or forages were taken at harvest by collecting number of randomly chosen sub-samples from each plot and mixed to create a representative sample from each plot. The samples were subjected to chemical analysis, the determined parameters were nutrients and trace elements. The plant samples were dried, grounded and passed through 2 mm sieve. All samples were analyzed for total N using a modified micro-Kjeldhal digestion according to A.O.A.C. (1990), for total P (Olson and Sommers, 1990) and for K using flame emission photometry (Jackson, 1973). Micronutrients and heavy metals were determined using atomic absorption spectrophotometer in dry ash digestion according to (Chapman and Pratt, 1961). Samples of wheat grain were taken for chemical analysis. The soil in each plot was sampled after wheat harvest for chemical analysis.

Statistical analysis**:** The data were subjected to the proper statistical analysis using MSTAT program (MSTAT-C, 1988). For means comparison Least Significant Difference (LSD) at 5% level was applied.

RESULTS

Crop Rotation 1 Wheat**:** It is worthy to mention that the calculations of nutrients applied to the field trials through compost application at 10 m^3 (Table 1) were 94.5 kg N, 36.4 kg P, 189 kg K, 1.27 kg Fe, 2.1 kg Mn, 427 g Zn and 350 g Cu. Data presented in Table 3, show the yields of wheat in the

Table 3. Yields of wheat, in the first season (rotation 1).

Treatment	Biological yield (t fd^{-1})	Grain yield (t fd^{-1})	Straw yield (t fd^{-1})
Control (100% fertilizer)	2.62	0.58	2.04b
Compost 10 m^3 fd^{-1}	3.30	0.63	2.67a
Grand mean	2.96	0.60	2.36
cv %	18.73	31.97	17.42
Probability	0.08	0.21	0.04*
LSD at 0.05	ns	ns	0.61

Note: Numbers in each column followed by different letters are significantly different at P < 0.05.

Table 5. Yield of wheat, in the third season (rotation 1).

Treatment	Grain yield (t fd^{-1})	Relative to C/C/C (%)	Straw yield (t fd^{-1})	Relative to C/C/C (%)	Biological yield (t fd^{-1})	Relative to C/C/C (%)
O/O/O	1.18b	-	2.96b	-	4.17b	-
O/C/O	1.37b	19	3.91ab	32	5.29ab	28
C/O/C	1.70a	44	3.45ab	17	5.15ab	24
C/C/C	1.88a	59	4.35a	47	6.23a	50
Probability	< 0.001***	-	0.47*	-	0.003**	-
LSD at 0.05	0.28	-	1.33	-	1.26	-

Values for each mean within a column, followed by the same letter, are not significantly different at P = 0.05.
Note: O = no compost application and C = compost applied for each season.

first season. The yields achieved are equivalent to the corresponding yields in the district. The yield of wheat straw was significantly increased by compost applied at 10 m^3 fd^{-1} (P < 0.05), and although there were increases in grain and biological crop yield, these did not achieve statistical significance indicating the nature of compost application for its slow acting in the 1st season of application.

***b) Forage maize*:** In the second season of crop rotation 1, cumulative and residual effects are demonstrated due to compost previously and/or currently applied at 10 m^3 fd^{-1}. Highly significant effects on fresh weight (P < 0.001) and dry matter accumulation (P < 0.01) yields obtained are presented in Table 4 and Fig. 2. Data indicated that there was a significant residual effect of the previous season's compost application compared with the control (fertilizer only). Further addition of compost to the previously untreated plots encouraged yield increases, although the increment statistically was insignificant.

Table 4. Yields of forage maize, in the second season (rotation 1).

Treatment	Fresh yield (t fd^{-1})	Dry yield (t fd^{-1})
O/O	3.66c	0.48b
C/O	5.40b	0.80a
O/C	6.87ab	1.07a
C/C	7.05a	1.11a
Probability	< 0.001***	0.002**
LSD at 0.05	1.55	0.32
cv %	22.00	29.80

Note: O = no compost applied; C = compost applied at 10 m^3 fd^{-1} in previous / current seasons. Numbers in each column followed by different letters are significantly different at P < 0.05.

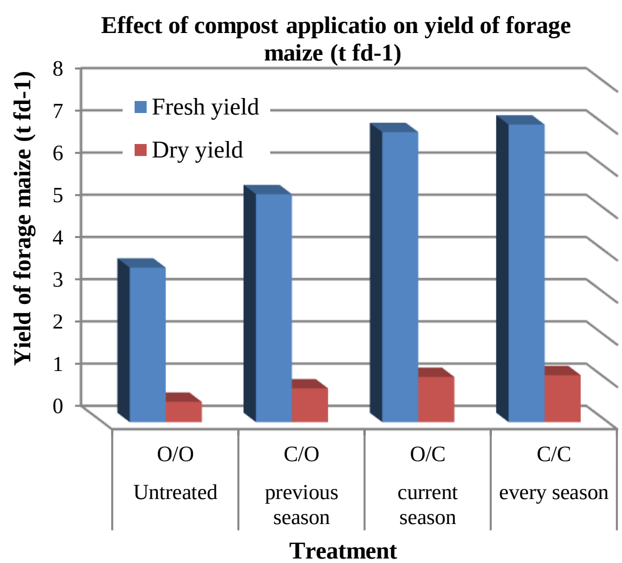

Figure 2. Yield of forage maize (fresh and dry basis, t fd^{-1}), in the second season (rotation 1).

***c) Wheat*:** The third crop in the rotational sequence on this trial was wheat following two previous seasons of applications of decanting compost to wheat and maize. Cumulative and residual effects can now be examined for experimental plots receiving compost continuously for three seasons (C/C/C), for the first and third seasons (C/O/C), and for the second season only (O/C/O). The results show

Table 6. Maize yield components, Cumulative Effects in the fourth season (rotation 1).

Treatment	Plant height (cm)	Ear weight (g)	Grain yield (t fd^{-1})	Relative to O/O/O/O (%)	Straw yield (t fd^{-1})	Relative to O/O/O/O (%)	Biological yield (t fd^{-1})	Relative to O/O/O/O (%)
O/O/O/O	192c	103c	1.56c	-	2.42c	-	3.98c	-
O/C/O/C	210a	230a	3.68a	136	4.05b	67	7.72b	96
C/O/C/O	189b	202b	3.26b	109	4.17b	71	7.40b	86
C/C/C/C	222a	239a	3.70a	137	5.01a	107	8.71a	119

Values within a column, followed by the same letter, are not significantly different at P = 0.05.
Note: O = no compost applied; C = compost applied at 10 m^3 fd^{-1} in previous / current seasons.

Table 9. Berseem yield, cumulative effects in the 3*rd* season (rotation II).

Treatment	Second cut		Third cut		Total yield			
	Fresh wh. fd^{-1} (t)	Dry wh. fd^{-1} (t)	Fresh wh. fd^{-1} (t)	Dry wh. fd^{-1} (t)	Fresh wh. fd^{-1} (t)	Relative to C/C/C (%)	Dry wh. fd^{-1} (t)	Relative to C/C/C (%)
O/O/O	7.2b	1.2b	8.7b	1.6b	15.9b	-	2.8b	-
O/C/O	10.1a	1.9a	11.0ab	2.9ab	19.6ab	23	4.8a	71
C/O/C	10.2a	1.7ab	17.3a	3.6a	24.5a	54	5.3a	89
C/C/C	10.6a	1.7ab	11.7ab	2.8ab	22.2ab	40	4.5a	57
Probability	0.006**	0.023*	0.012*	0.009**	0.012*	-	0.003**	-
LSD at 0.05	2.6	0.6	4.1	1.4	6.7	-	1.6	-

important residual and cumulative effects of compost application on the yield performance of wheat (Table 5). The residual value of compost applied in the previous season increased grain and straw yield relative to the unamended control by 19% and 32%, respectively, although these treatments were not significantly different at P = 0.05. On average, grain yield was raised 44% to 1.7 t fd^{-1} compared to the control for compost applied to this crop and in the first season of the trial. Such results will need more attention to fertilization management, as well as follow-up sustainable soil fertility to improve nutrient acquisition more than the application of synthetic fertilizers.

***d) Maize*:** Data of maize yield grown in the fourth season (summer season of 2019) of the crop rotation I are presented in Table 6 and Fig. 3. Inorganic fertilizer was applied to all the experimental plots including the control treatment, which is considered the normal farmer practice (100% N). Highly significant effects of compost application on the yield performance were detected by ANOVA (grain yield P < 0.001) for alternate dressings and the cumulative plots (C/C/C/C). Compost application in each season enhanced maize growth and increased straw yield of maize by 107% and grain yield by 137%, relative to the control response (no compost applied).

Crop Rotation II ***Barley*:** No significant effects were observed in barley crop yields due to the high variability of the data (CVs %), although there was a tendency of increased crop yield with the addition of compost at 10 m^3 fd^{-1} (Table 7). Yields were comparable to those achieved in wheat trial in the 1st crop rotation.

***b) Sesame*:** Highly significant effects (P < 0.001) were observed on sesame seed yield and total crop yield due to residual, current and cumulative effects of compost application, although the effect on crop height was less significant (P < 0.05), Table 8. Seed yield increased from 160 kg fd^{-1} in the control treatment (fertilizer at 60 kg N fd^{-1}) to about 435 kg fd^{-1} for the residual and current compost treatment, to 590 kg fd^{-1} on the cumulative compost treatment (The calculations of seed yield increase over the control treatment reached up 270% increase over the control). The increase in biological yield was proportionately greater (400%).

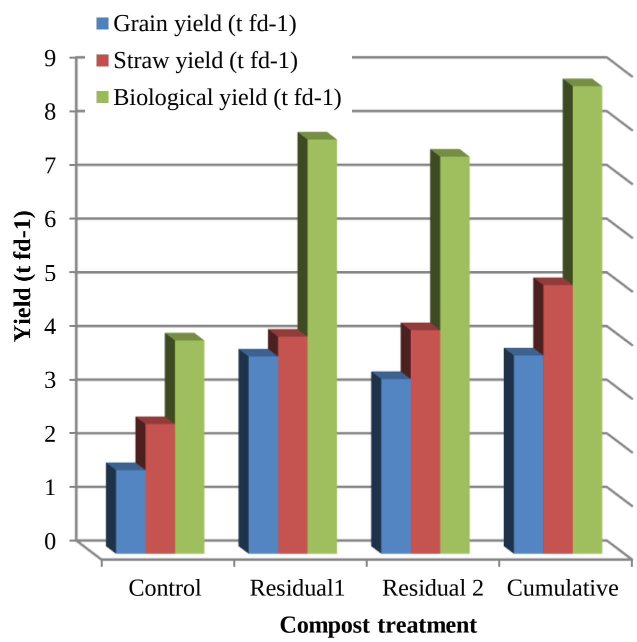

Figure 3. Cumulative effects of compost application on maize yields (crop rotation 1)

Table 7. Yields of barley, in the 1st season (rotation II).

Treatment	Total yield (t fd^{-1})	Grain yield (t fd^{-1})	Straw yield (t fd^{-1})
Control	3.43	1.25	2.18
Compost 10 m^3 fd^{-1}	3.64	1.30	2.35
Grand mean	3.54	1.27	2.27
cv %	35.5	0.48	35.6
Probability	> 0.05 ns	> 0.05 ns	> 0.05 ns

Table 8. Yields of sesame, cumulative effects in the 2*nd* season (rotation II).

Treatment	Plant height (cm)	Seed yield (kg fd^{-1})	Biological yield (t fd^{-1})
O/O	86.4b	160 d	0.38d
C/O	97.0ab	435 c	0.98c
O/C	98.0ab	437 b	1.37b
C/C	108.0a	590 a	1.91a
Probability	0.034*	<0.001***	<0.001***
LSD at 0.05	13.70	64.4	0.20
cv %	11.47	13.7	13.90

Numbers in each column followed by different letters are significantly different at P<0.05

Note: O = no compost applied; C = compost applied at 10 m^3 fd^{-1} in previous / current seasons

***c) Berseem*:** Berseem was the third crop to be grown in the rotation, following applications of compost to barley (winter 2017/18) and sesame. The trial examined the cumulative (C/C/C, C/O/C) and residual (O/C/O) effects of compost application on forage production. Data presented in (Table 9 and Fig. 4) for the second and third cuts only because volunteer cereal from the previous winter season compromised the taking of accurate and representative yield measurements for the first cut.

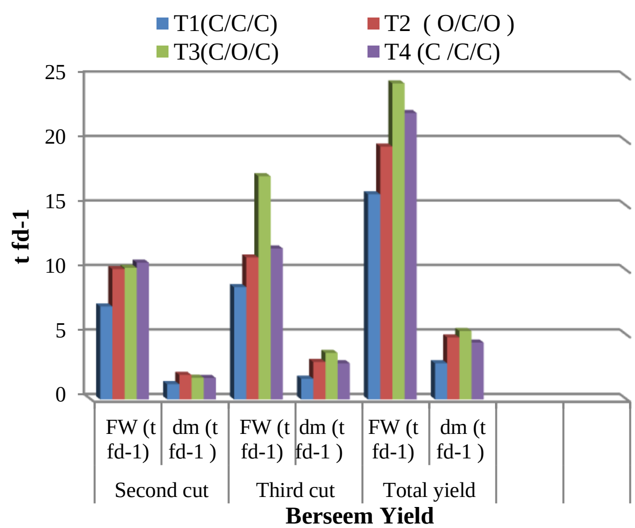

Figure 4. Cumulative Effects of compost application on berseem yields (Crop Rotation 2).

***d) Grain sorghum*:** Yield data of sorghum, grown in the fourth season (summer, 2019) of crop rotation 2 are presented in Table 10. Inorganic fertilizer was applied to all the experimental plots and the control condition reflected normal farmer practice. Highly significant effects of due to compost application on yield performance were detected by ANOVA (grain yield P < 0.001) for alternate dressings and the cumulative plots (C/C/C/C).

***Relative yields*:** Data presented in Table 11 shows that the residual and cumulative effects of compost applied to both crop rotations have relative yields response to compost application compared to the treatment of normal farmer practice. The mean relative yields in crop rotation I (Wheat - Forage maize - Wheat - Grain maize) decreased sharply than crop rotation II (Barley - Sesame - Berseem - Grain sorghum) when compost was applied each season (cumulative), before crop and prior season (residual), respectively (Table 11 and Figs. 5 and 6). Data in the same Table, also show that there is significant difference, a clear pattern of cumulative and residual benefits. Crop yields from seasonal application of compost are generally significantly greater than those resulting from applications of compost in alternate seasons. Significant differences are also observed between the two alternate seasonal application treatments, with crop responses being greater when compost is applied in the season of crop production compared with the residual effect of compost applied in the previous season.

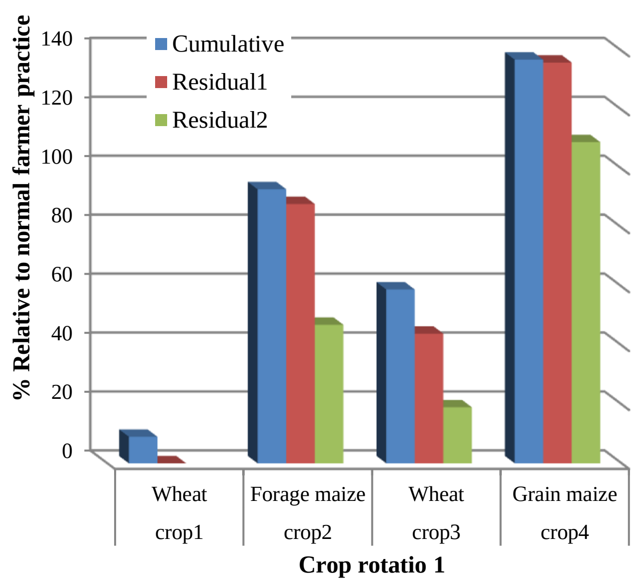

Figure 5. Residual and cumulative effects of compost applied in consecutive and alternate seasons

(Residual 1 and 2) on economic crop yield relative to normal farmer practice

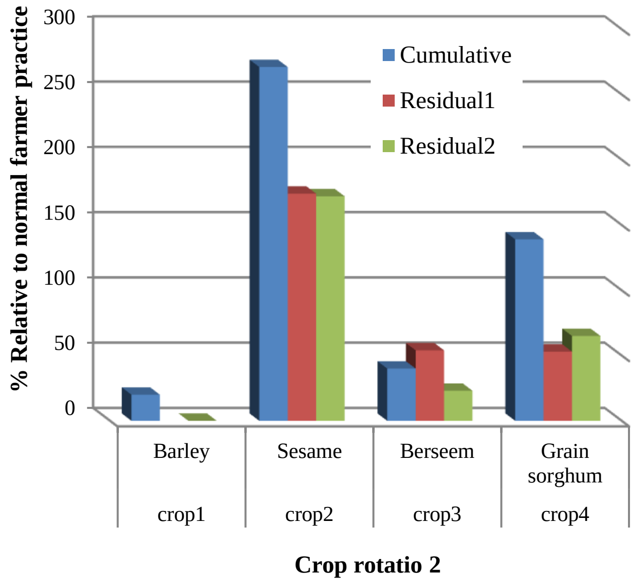

Figure 6. Residual and cumulative effects of compost applied in consecutive and alternate seasons (Residual 1 and 2) on economic crop yield relative to normal farmer practice.

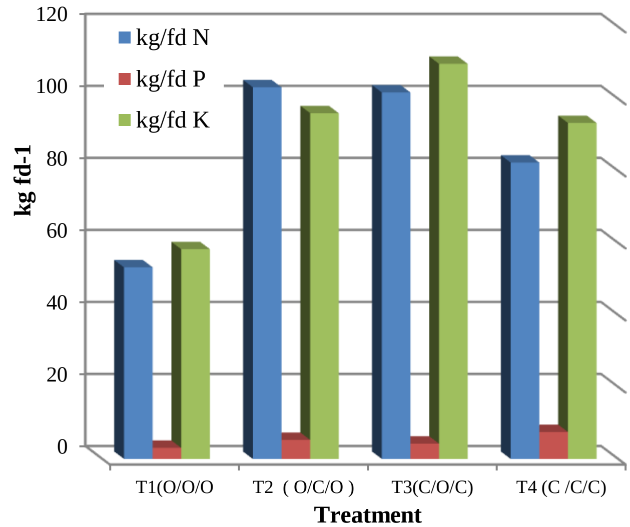

Figure 7. Macro nutrient content in berseem kg fd^{-1} (on dry matter basis).

Table 10. Sorghum yield components, cumulative effects in the 4*th* season (rotation II)

Treatment	Plant height (cm)	Ear weight (g)	Grain yield (t fd^{-1})	Grain yield % of O/O/O/O	Straw yield (t fd^{-1})	Straw yield % of O/O/O/O	Biological yield (t fd^{-1})	Biological yield % of O/O/O/O
O/O/O/O	172a	52c	0.75c		2.57b		3.31b	
O/C/O/C	176a	82b	1.15b	53	3.48ab	35	4.64a	40
C/O/C/O	173a	73b	1.24b	65	3.20ab	24	4.44a	34
C/C/C/C	177a	127a	1.79a	139	3.66a	42	5.45a	65

Means within a column, followed by the same letter, are not significantly different at P = 0.05.

Table 11. Residual and cumulative effects of compost applied in consecutive and alternate seasons on economic crop yield relative to normal farmer practice.

Crop	Fertilizer response (as 100%)	Increase above fertilizer response (%): Compost applied in each season	Application in alternate years: Before crop	Application in alternate years: Prior season
Crop Rotation 1				
Wheat	100 a	95 a	-	-
Forage maize	100 c	93 a	88 ab	47 b
Wheat	100 b	59 a	44 a	19 b
Grain maize	100 c	137 a	136 a	109 b
Mean	100	74.5	89.3	58.3
Crop Rotation 2				
Barley	100 a	20 a	-	-
Sesame	100 d	271 a	174 b	172 c
Berseem	100 b	40 ab	54 a	23 ab
Grain sorghum	100 c	139 a	53 b	65 b
Mean	100	117.5	93.7	86.7

Table 12. Chemical composition of wheat grain, Cumulative Effects (Units: nutrients as %; other elements at mg kg^{-1}).

Treatment	N	P	K	Fe	Mn	Zn	Cu
O/O/O	1.55a	0.20a	0.58a	317.0a	38.3a	44.8a	4.52a
O/C/O	1.75a	0.17a	0.58a	360.9a	45.1a	61.2a	3.36a
C/O/C	1.55a	0.22a	0.58a	333.9a	43.9a	46.8a	5.49a
C/C/C	1.80a	0.18a	0.58a	356.2a	44.7a	48.6a	5.66a
Probability	0.121	0.306	0.615	0.727	0.664	0.226	0.572
Significance	ns	ns	ns	ns	ns	ns	ns

Values for each mean within a column, followed by the same letter, are not significantly different at P = 0.05.
Note: O = no compost applied; C = compost applied at 10 m^3 fd^{-1} in previous / current seasons.

Table 13. Chemical composition of berseem (2*nd* cut), Cumulative Effects (Units: nutrients as %; other elements at mg kg^{-1}).

Treatment	N	P	K	Fe	Mn	Zn	Cu
O/O/O	1.90a	0.11a	2.08a	447.0a	36.6a	27.4b	3.57a
O/C/O	2.15a	0.11a	2.00a	399.9a	28.8a	34.9a	2.46a
C/O/C	1.92a	0.08a	2.07a	378.3a	37.6a	26.3b	2.75a
C/C/C	1.87a	0.17a	2.12a	402.5a	33.8a	36.1a	2.28a
Probability	0.663	0.512	0.828	0.584	0.781	0.003	0.685
Significance	ns	ns	ns	ns	ns	**	ns
LSD at 0.05	-	-	-	-	-	5.64	-

Values for each mean within a column, followed by the same letter, are not significantly different at P = 0.05.
Note: O = no compost applied; C = compost applied at 10 m^3 fd^{-1} in previous / current seasons.

Table14. Chemical analysis of soil after wheat harvest, cumulative effects (Units: EC as dS m^{-1}; OM as %; other elements as mg kg^{-1}).

Treatment	pH	EC	OM	N	P	K	Fe	Mn	Zn	Cu
O/O/O	8.04a	0.22a	0.71a	1748a	46.3a	754a	6381a	85.2a	12.7a	3.9a
O/C/O	7.83a	0.25a	1.19a	1972a	50.3a	827a	6432a	87.4a	23.6a	13.5a
C/O/C	7.77a	0.27a	1.24a	2333a	77.3a	812a	9021a	119.2a	33.7a	20.2a
C/C/C	7.76a	0.25a	1.17a	1138a	60.7a	870a	7120a	94.7a	28.2a	15.5a
Probability	0.092	0.319	0.372	0.245	0.371	0.486	0.362	0.381	0.312	0.336
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Values for each mean within a column, followed by the same letter, are not significantly different at P = 0.05.
Note: O = no compost applied; C = compost applied at 10 m^3 fd^{-1} in previous / current seasons.

Table 15. Chemical analysis of soil after berseem, Cumulative Effects (Units: EC as dS m^{-1}; OM as %; other elements as mg kg^{-1})

Treatment	pH	EC	OM	N	P	K	Fe	Mn	Zn	Cu
O/O/O	7.92a	0.18b	1.07a	1793a	65.3a	739.7a	6811a	72.6a	12.8a	3.97a
O/C/O	7.78a	0.22b	1.08a	2217a	76.7a	826.7a	7681a	81.0a	22.0a	10.00a
C/O/C	7.72a	0.25a	1.09a	1363a	70.3a	798.0a	6134a	83.4a	15.7a	6.15a
C/C/C	7.78a	0.24a	1.11a	1540a	61.3a	681.7a	6446a	79.2a	11.4a	3.07a
Probability	0.172	0.051	0.892	0.112	0.942	0.097	0.503	0.453	0.357	0.315
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Values for each mean within a column, followed by the same letter, are not significantly different at P = 0.05.

***Chemical composition of wheat grains and berseem*:** Wheat grain nutrient analysis is summarized in Table 12. ANOVA did not detect significant effects on nutrient contents which were small, being below the levels normally recommended

for optimum production. Trace element concentrations were adequate, except for copper which was low. Similar magnitude was evident for berseem nutrient concentrations from the second cut where ANOVA did not detect any statistically significant differences between the treatments with the exception zinc (P = 0.003) where compost increased concentrations in the crop (Table 12 and Figs. 7 and 8). Generally, the nutrient and trace element concentrations were generally small and below the recommended levels for optimum yield, except zinc which achieved adequacy levels under cumulative compost applications.

***Soil characteristics*:** The soil in each plot was sampled after wheat harvest (3*rd* crop rotation I) for chemical analysis and the results are presented in Table 14. While the effects of the treatments on soil concentrations were not statistically significant, some trends for increasing EC, OM, nutrients, and some heavy metals are discernible.

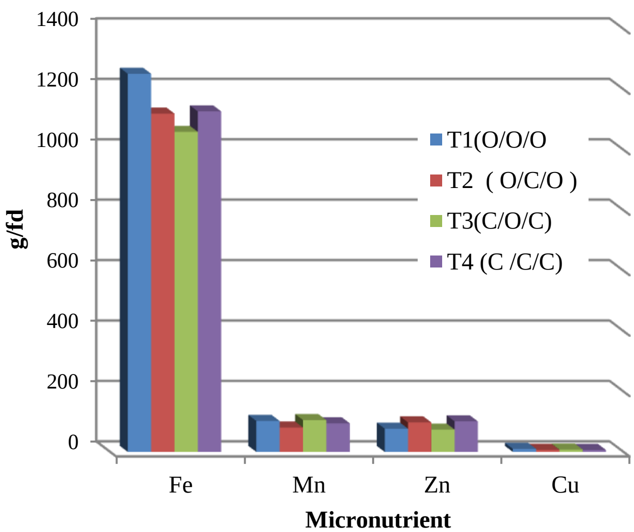

Figure 8. Micro nutrient content in berseem kg fd^{-1} (on dry matter basis).

There was also a trend of decreasing pH. The maximum application after three seasons in this cumulative trial is only 30 m^3 fd^{-1}, and the continuation of this trial is important to monitor changes in soil chemistry in the longer term. For berseem (Table 15), no statistically significant effects of the treatments were detected by ANOVA, although electrical conductivity (EC) almost achieved significance (P = 0.05). Similar trends to those observed for wheat (Table 14) were evident but not as pronounced.

DISCUSSION

The obtained results indicated that the repeated application of compost to previously treated plots increased yields of wheat further. This reveals the importance of cumulative beneficial effects on crop performance, presumably due to multiple elements in compost (macro and micronutrients, trace elements, and organic matter). However, the major cumulative value of compost was demonstrated by the large and significant increase in crop yield performance measured for plots receiving compost on a regular basis. Grain production was raised by approximately 60% after three consecutive dressings of compost compared with the control treatment managed according to standard farmer practice.

The results suggested that no significant improvement in grain yield of maize was apparent from applying compost in each growing season, compared with applications in alternate seasons, when this coincided with the maize crop (O/C/O/C), Table 6 and Fig. 3. However, the overall biological yield of maize was raised at the highest frequency of compost use due to a significant increase in straw production for this treatment compared to supplying compost to alternate crops. All yield components of maize were significantly improved compared to the conventional management regime, including those plots where compost was supplied to the previous crop (C/O/C/O).

In crop rotation II sesame is particularly sensitive to excessive fertilization and can result in excessive vegetative growth at the expense of seed production (as found in the cumulative trials undertaken by the Cairo Compost Disposal Study after six applications of compost over three years at a high rate of 20 m^3 fd^{-1} (CSDS, 1999). This did not occur in the current trial, but the disproportionate increase seen in biological crop yield compared to seed production may indicate this effect (Table 8). Consequently, farmers need to take care when applying compost regularly to avoid over-fertilizing certain crops.

Compost application increased the yield of berseem and was shown to have important cumulative and residual effects. The highest overall fresh and dry matter productivity was obtained with compost applied to alternate summer season crops. Under this regime, forage yield increased by more than 50% relative to the control on a fresh weight basis, and dry matter production was raised by almost 90% compared to conventional farmer practice without compost application. The results show that no additional yield benefit is gained from consecutive applications of compost in both summer and winter seasons for berseem production on reclaimed desert soil.

Compost application in each season increased straw yield of sorghum by 42% and grain yield by 170%, relative to the control response. All yield components of sorghum were significantly improved compared to the conventional management regime, including those plots where compost was supplied to the previous crop (C/O/C/O). In contrast to maize, compost application to all crops in the rotation significantly increased grain yield of sorghum, but there was no significant difference in straw yield compared with applying compost in alternate seasons.

These data emphasized the major cumulative and residual agronomic value of compost in arable crop production on

reclaimed desert soil. Compost can markedly increase the yields of arable crops on these impoverished soils significantly above that which is possible by conventional intensive farming practices. However, crops vary in sensitivity to the cumulative effects of compost addition and the most economic regime may generally be achieved by spreading compost in alternate seasons. The present results are confirmed by several investigators (Gong *et al.*, 2009; Enke *et al.*, 2010) found that long-term addition of organic manure has the most beneficial effect on grain yield of wheat and maize. Also, (Tejada and Gonzalez, 2003) showed that compost application in 2-continuous years increased the number of grains spikes^{-1}, 1000 grain weight and the number of spikes and grain wheat yield. This positive effect was mainly due to a better N supply with the compost application. Also, (Sefidkoohi *et al.*, 2012; Abd El Lateef *et al.*, 2019b) came to similar conclusion.

The results of residual and cumulative effects of compost applied in consecutive and alternate seasons on economic crop yield relative to normal farmer practice indicted that crop yields vary according to crop rotation and compost treatment (Table 11 and figs. 5 and 6). For instance, sesame yields the 2*nd* crop in rotation II after two applications of compost were considerably greater (by 271%) than that from the recommended rate of fertilizer. The response of sesame to a single application of compost, either made immediately prior to sowing or as a residual effect of application to the previous crop, also gave greater yields than fertilizer (by 174%) but were lower than that from the cumulative compost treatment. Similar conclusion was reported by (Abd El Lateef *et al.*, 2019a). With respect to soil analysis (Miller and Miller, 2000) highlighted that organic material application to cropland could affect soil properties, but the effects generally may not be apparent over a short time period. In particular, (Tittarelli *et al.*, 2017) found that the easiest way to study the agricultural value of stabilized organic matter is to calculate both the amount of organic matter and phytonutrients. The slow release of these nutrients has resulted in increased yields, making it difficult to quickly assess the true agricultural value of these organic substances as additives. However, due to significant differences between experimental methods, climates, soil types and organic matter properties, care must be taken in generalizing the effects of compost and biowaste applications on soil-plant systems. (Bhardwaj and Tyagi, 1994; Ghosh and Shah, 1997; Singh and Agarwal, 2004) reported increased NPK uptake in wheat when FYM was applied. There was no significant difference between direct and residual in respect to Mn concentration (in either year) and K concentration (in second year of study).

This should may be compared with the relatively small cumulative and residual benefits by the following winter season crops, whilst the responses to the subsequent summer season were much greater. The seasonal pattern of responses suggests that there may be other climatic factors influencing how the cumulative and residual benefits are expressed in the extent of crop yield increases in winter and summer seasons. Several researchers have come to similar results on the beneficial role of organic amendments on crop yields and soil improvement (Gong *et al.*, 2009; Enke *et al.*, 2010). Nehra and Hooda, 2002; Singh and Agarwal, 2004; Tawfik and Gomaa, 2005; Zeidan *et al.*, 2005; Yaduvanshi and Sharma, 2008; Tejada *et al.*, 2009; Yassen *et al.*, 2010; Sefidkoohi *et al.*, 2012; Ram *et al.*, 2014.

***Conclusion*:** These data emphasized the major cumulative and residual agronomic value of application compost in general and specifically in arable crop production on reclaimed sandy soils. Compost can markedly increase the yields of arable crops on these impoverished soils significantly above that which is possible by conventional fertilizers application. However, crops vary in sensitivity to the cumulative effects of compost addition and the most economic regime may generally be achieved by spreading compost in alternate seasons. In addition, applied manures was found to raise the soil pH in acid soils (Sanchez and Miller, 1986; Spaccini *et al.*, 2002; Ogunlade *et al.*, 2006; Olatunji *et al.*, 2006). Furthermore, repeated application of organic residues on soils has long-lasting positive effects on soils (Adeniyan and Ojeniyi, 2003; 2005).

In conclusion, organic farming system conserves the ecosystem, due to it contains of symbiotic life forms are cultured ensuring optimum soil life forms of microorganism's action (biological activity, which maintains soil fertility. Regarded application synthetic fertilizers cause harmful effects for soil and aerial environment because the inorganic fertilizers mainly contain a large quantity of major nutrients viz., NPK that may be the main factor of lessening soil fertility. In addition, neglecting the use of organic manures and biofertilizers are the main reason of deterioration soil health and in turn ill-effects on plants, human being and livestock (Choudhry, 2005).

***Abbreviation*:** fd^{-1} = One feddan = 4200 m^2

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